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Reconsideration of the stratigraphic position of the boundary between the Berriasian and the Nemausian (= Valanginian sensu stricto)

By

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With 3 text figures

ABSTRACT

The study of the ammonite distribution in the Lower Cretaceous beds N and NW of Los Miravetes (Río Argos, W of Caravaca, SE Spain), compels us to draw the boundary between the Berriasian and Valanginian sensu stricto between the *Berriasella (Berriasella) picteti* Subzone and the *Tirnovella alpillensis* Subzone. The latter subzone was introduced as a substitute for the *Berriasella (Berriasella) callisto* Subzone of Le Hégarat (1971), because, although both subzones embrace the same biochronologic interval, the ammonite associations of the two differ fundamentally: in addition to the known *callisto* association of merely "Berriasian" ammonites, the *T. alpillensis* Subzone contains an equally large number of renownedly 'Valanginian' ammonite forms appearing at its base. The boundary proposed here coincides with the appearance of *Lorenziella hungarica*, which provides a means to correlate this level outside the Mediterranean faunal province.

The transformation from a pure Berriasian ammonite association into a clear Valanginian association definitely has not the abruptness that invited so many stratigraphers to choose this boundary as the one between the Jurassic and Cretaceous systems.

Finally arguments are adduced to return to the old concept of the Valanginian Stage and to regard the Berriasian as its lower substage. For the upper substage of the Valanginian (= Valanginian sensu stricto) the name Nemausian (Sarran d'Allard, 1875, 1881) is available, which has explicitly been introduced to cover the stratigraphic interval between the Berriasian and the Hauterivian.

KURZFASSUNG

Die Verteilung der Ammoniten in der Unterkreide-Abfolge N und NW von Los Miravetes (Rio Argos, W von Caravaca, SE-Spanien) zwingt uns die Grenze zwischen dem Berrias und dem Valangin s. str. zwischen der *Berriasella (Berriasella) picteti*-Subzone und der *Tirnovella alpillensis*-Subzone zu legen. Letztgenannte Subzone wurde als Ersatz für die *Berriasella (Berriasella) callisto*-Subzone von Le Hégarat (1971) eingeführt, da die Ammoniten-Vergesellschaftungen der beiden Zonen beträchtlich unterschiedlich sind, obwohl beide Subzonen dasselbe biochronologische Intervall umfassen. Zusätzlich zu der bekannten *callisto*-Vergesellschaftung aus reinen „Berrias-Ammoniten" enthält die *T. alpillensis*-Subzone eine vergleichsweise große Anzahl von typischen „Valangin-Ammoniten", Formen also, die an der Basis der Zone einsetzen. Die hier vorgeschlagene Grenzziehung fällt mit dem Einsetzen von *Lorenziella hungarica* zusammen, dies gibt die Möglichkeit zur Korrelation auch außerhalb der mediterranen Faunenprovinz. Die Umbildung von einer reinen Berrias Ammoniten-Vergesellschaftung zu einer reinen Valangin-Vergesellschaftung zeigt nicht die Schärfe, die manche Bearbeiter verleitet hat, diese Grenze als Jura/Kreide-System-Grenze zu wählen. Schließlich werden Argumente angeführt zum alten Konzept für die Stufe Valangin zurückzukehren und das Berrias als untere Unterstufe zu betrachten. Für die obere Unterstufe des Valangin (= Valangin s. str.) ist der Name Nemausian (Sarran d'Allard, 1875, 1881) verfügbar; er wurde eingeführt für das Intervall zwischen Berrias und Hauterive.

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INTRODUCTION

A Dutch equipe of eight stratigraphers and palaeontologists is studying the biostratigraphy of the Lower Cretaceous along the Rio Argos, W of Caravaca in SE Spain. This study is partially financed by the Netherlands Organization for the Advancement of Pure Scientific Research. The zonation of dinoflagellates, pollen, coccolithophorids, nannoconids, calpionellids, benthic and planktic foraminifera are being integrated with the ammonite zonation. Also the cyclicity of the deposits is studied, which facilitates the application of numerical stratigraphical methods.

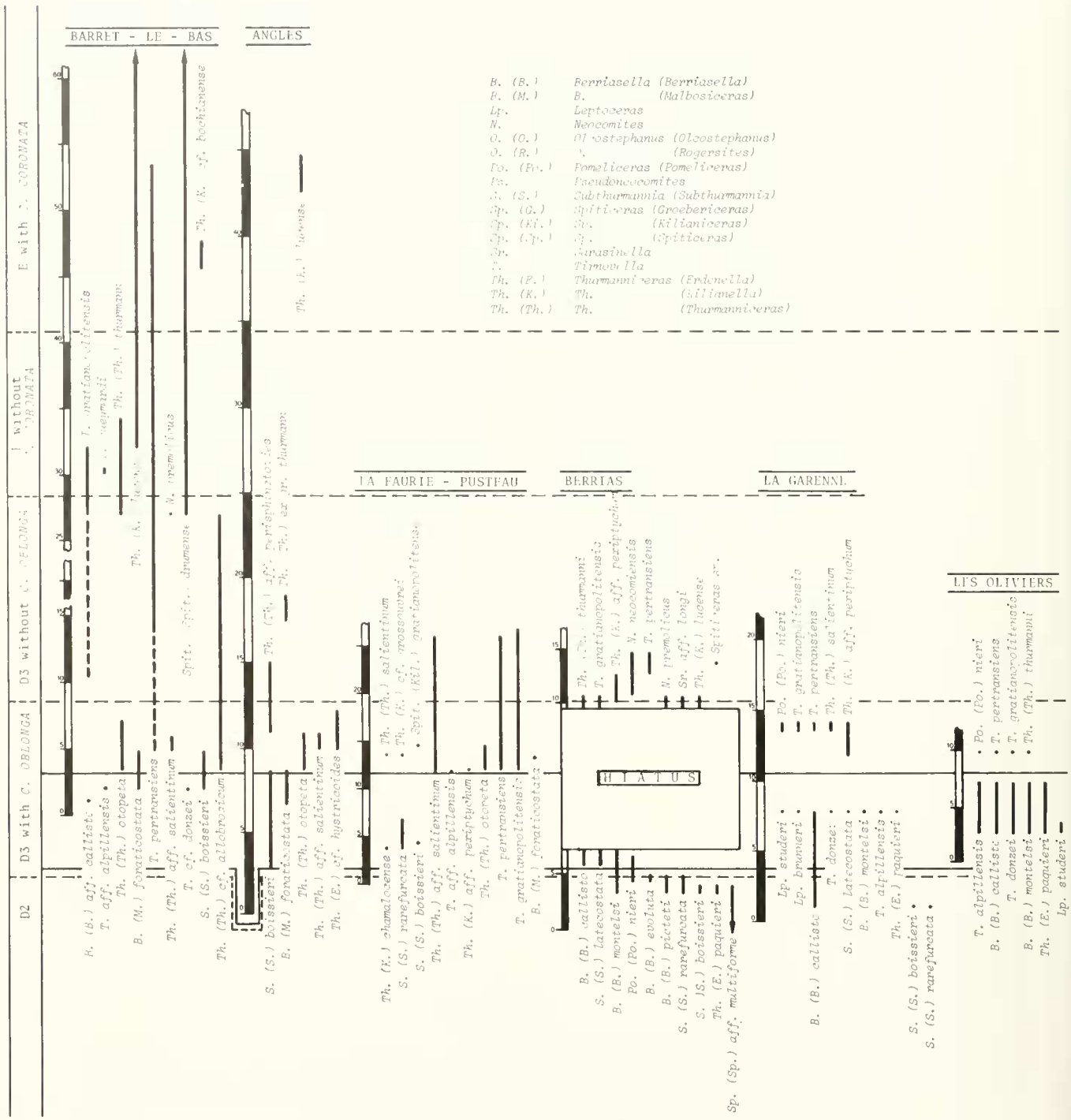
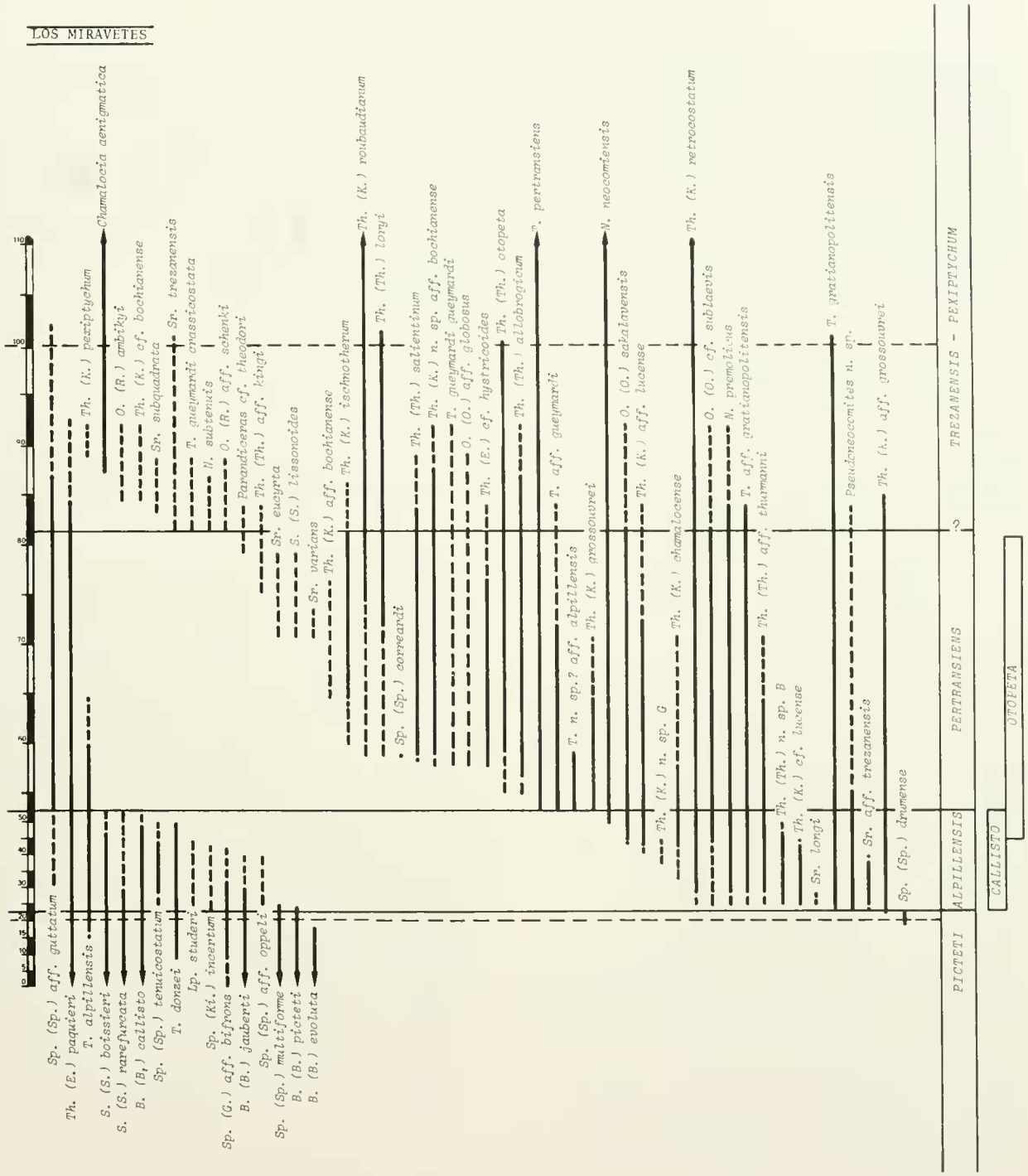


Figure 1. Comparison of the ammonite ranges in various French sections with those in the Los Miravetes section. Correlation of the sections is primarily based on calpionellid biohorizons (left side and horizontal dashed lines). The base of calpionellid zone E has not yet been traced in Los Miravetes. Solid horizontal lines delimit ammonite subzones (right side). The intervals occupied be LE HÉGARAT's *callisto* Subzone and THIEULOY's *otopeta* Zone are depicted for comparison. In order to save space only the scales in metres alongside the published lithological columns are drawn and accomodated so that the biohorizons are in line; the columns are omitted.

Therefore we began our investigation with the as accurate as possible construction of the lithologic columns. The lithology of the entire sequence consists of a monotonous alternation of grey marlstone beds with light grey marly limestone beds. Additional sandstone turbidite beds occur in the Aptian. The Lower Cretaceous along the Río Argos is more than 1500 m thick and shows great similarity with the Lower Cretaceous sequence of the Fosse Vocontienne in SE France. Unfortunately a regional unconformity makes that upper Aptian, lower Albian, and middle Albian beds are missing. Our equipe has spent seven months in collecting ammonites from this sequence. This resulted in a collection of some 8000 identifiable ammonites. After identification, their ranges were plotted alongside the lithologic columns.

The study of the ammonite biostratigraphy was begun with the faunas of the uppermost Tithonian, Berriasian, and lower



Valanginian sensu stricto. The outcome of this study compelled the author to reconsider the stratigraphic positions of the Tithonian-Berriasian boundary and the boundary between the Berriasian and the Valanginian sensu stricto. During the Second Symposium on the Spanish Jurassic, Granada 1979, the author adduced arguments that the former boundary had best be chosen between the *Pseudosubplanites grandis* Subzone and the *Subthurmannia (Strambergella) subalpina* Subzone (Hoedemaeker, 1981). Here will be discussed where the boundary between the Berriasian and the Valanginian sensu stricto had best be chosen.

DATA FROM SOUTHEASTERN FRANCE

The abrupt virtually total renewal of the ammonite fauna at the boundary between the Berriasian and the Valanginian sensu stricto in SE France has since long been a well-known fact (Busnardo & Le Hégarat, 1965; Le Hégarat & Remane, 1968; Le Hégarat, 1971). All "Berriasian" perisphinctaceans are suddenly replaced by "Valanginian" ones: an almost complete stratigraphic segregation existed between reputedly "Berriasian" and renownedly "Valanginian" perisphinctaceans. Only the range of *Pomeliceras nieri* (Pict.) has been shown to be overlapping the ranges of *Tirnovella gratianopolitensis* (Sayn), *T. pertransiens* (Sayn), *Thurmanniceras (Thurmanniceras) thurmanni* (Pict. & Camp.), *Th. (Th.) salientinum* (Sayn), and *Thurmanniceras (Kilianella)* aff. *pexiptychum* (Uhl.) (Le Hegarat & Remane, 1968; Le Hégarat, 1971).

This is the reason why so many stratigraphers prefer to choose this boundary as the limit between the Jurassic and the Cretaceous systems (Zeiss, 1965; Wiedmann, 1968, 1974, 1975; Drushchits, 1975; Badaluta, 1975; Patrulius et al., 1976; and all those attendants of the "Colloque sur la limite Jurassique-Crétacé" who voted for this boundary, among which Le Hégarat, Enay, de Flandrin, and Thieuloy).

Recent bed by bed investigations of Remane & Thieuloy (1973), Thieuloy (1973, 1977b, 1979), and Allemann & Remane (1979) in the Barret-le-Bas, Angles, and La Faurie-Pusteau sections in SE France only seem to confirm this abruptness of the renewal of the ammonite fauna. Thieuloy showed that in an interval of only two metres thickness (Barret-le-Bas) the range of another reputedly "Berriasian" ammonite form, viz. *Subthurmannia (Subthurmannia) boissieri* (Pict.), is overlapping the ranges of *Thurmanniceras (Thurmanniceras) otopeta* Thieul., *Th. (Th.)* aff. *salientinum* Sayn, *Th. (Th.)* cf. *allobrogicum* (Kil.), and *Tirnovella* aff. *pertransiens* (Sayn).

The part of the calpionellid subzone D3 (which starts with the entry of *Lorentziella hungarica)* situated below the base of this interval of overlap, contains the ammonite association that according to Le Hégarat (1971) characterizes the *Berriasella (Berriasella) callisto* Subzone. This association consists only of "Berriasian" ammonite forms: *Berriasella (Berriasella) callisto* (d'Orb.) (Berrias, La Garenne, Les Oliviers), *B. (B.) montelsi* (Le Hég.) (La Garenne), *Tirnovella alpillensis* (Maz.) (La Garenne, Les Oliviers), *T. donzei* Le Hég. (La Garenne, Les Oliviers), *Subthurmannia (Subthurmannia) boissieri* (Pict.) (Pusteau, Angles, Barret-le-Bas), *S. (S.) rarefurcata* (Pict.) (Pusteau), *Thurmanniceras (Erdenella) paquieri* (Sim.) (La Garenne), *Leptoceras studeri* (Oost.) (La Garenne, Les Oliviers), *Lp. brunneri* (Oost.) (La Garenne), *Thurmanniceras (Kilianella) chamalocense* (Maz.) (Pusteau), *Pomeliceras (Pomeliceras) nieri* (Pict.) (Berrias), and *S. (S.) latecostata* (Kil.) (Berrias, La Garenne). From other sections have been reported: *S. (S.) romani* (Maz.), *Berriasella (Malbosiceras)* aff. *rouvillei* (Math.), and *Spiticeras (Kilianiceras) damesiforme* Djan. This completes the impoverished ammonite association that was hitherto thought to characterize the *B. (B.) callisto* Subzone.

The part of the calpionellid subzone D3 between the base of the 2 m interval of overlap and the level in which the marked decline in the frequency of *Calpionellopsis oblonga* is situated, is characterized by the sudden entry of many renownedly "Valanginian" ammonite forms, viz. *Tirnovella pertransiens* (Sayn) (Pusteau, La Garenne, Les Oliviers), *T. gratianopolitensis* (Sayn) (= *Th. thurmanni* [Pict. & Camp.] in Le Hégarat & Remane, 1968, pl. 1, fig. 5) (Les Oliviers, Pusteau, La Garenne), *Thurmanniceras) (Thurmanniceras otopeta* Thieul. (Barret-le-Bas, Angles, Pusteau), *Th. (Th.) salientinum* Sayn (Pusteau), *Th. (Th.)* aff. *salientinum* (still uninterpretable) (Barret-le-Bas, Angles), *Th. (Th.)* cf. *allobrogicum* (Kil.) (Barret-le-Bas), *Th. (Th.)* aff. *thurmanni* (Pict. & Camp.) (= *Th. gratianopolitensis* Sayn, in Le Hégarat & Remane, 1968, pl. 1, fig. 5) (Les Oliviers), *Th. (Th.)* aff. *perisphinctoides* (Uhl.) (possibly conspecific with *Th.* [*Th.*] *loryi* Sayn) (Angles), *Thurmanniceras (Kilianella)* aff. *pexiptychum* (Uhl.) (Le Hégarat & Remane, 1968, pl. 1, fig. 4) (Pusteau, La Garenne), *Th. (K.)* cf. *grossouvrei* Sayn (Pusteau), *Thurmanniceras (Erdenella)* cf. *hystricoides* (Uhl.) (Angles), and *Spiticeras (Kilianiceras) gratianopolitense* (Kil.) (Pusteau). The latter two are the only forms with "Berriasian" affinities, but have only been recorded from the lower Valanginian sensu stricto.

It should be noted that in 1965 Le Hégarat reported *Sarasinella* aff. *longi* (Sayn), *Neocomites premolicus* Sayn, and *Thurmanniceras (Kilianella) lucense* Sayn from bed 198 of the Berrias section. This bed is also the level in which the marked decline in the frequency of *Calpionellopsis oblonga* is situated. Because of this record, the latter species has been used by Wiedmann (1968) as index for his *Th. (K.) lucense* Zone, which would cover the biostratigraphic interval between the disappearance of *B. (B). callisto* and the appearance of *Th. (K.) roubaudianum.* Wiedmann's publication was however just preceeded by the publication of Le Hégarat & Remane (1968), in which they introduced their *Tirnovella pertransiens* Subzone for virtually the same beds with the same fauna of "Valanginian" ammonites, which therefore has priority. In 1971, however, Le Hégarat omitted these ammonite forms from his list of cephalopods found in bed 198 of the Berrias section, whereas Thieuloy (1979) reported the first *Th. (K.) lucense* and *N. premolicus,* together with the first *Tirnovella*

gueymardi (Sayn), and *Th. (K.)* cf. *bochianense* Sayn from much higher levels, viz. near the boundary between the calpionellid zones D and E.

Le Hégarat (1971) characterized the base of the *Th. pertransiens* Subzone by the sudden appearance of typically "Valanginian" ammonite forms in SE France. In the Barret-le-Bas, Angles, and La Faurie-Pusteau sections the lower boundary of the *T. pertransiens* Subzone should therefore be drawn at the base of the two metres thick interval in which the ranges of reputedly "Berriasian" and renownedly "Valanginian" ammonite forms are overlapping. Busnardo & Thieuloy (1979), however, separated the lower part of the *T. pertransiens* Subzone, as it was previously conceived, as a distinct biostratigraphic unit, the *Thurmanniceras (Thurmanniceras) otopeta* Zone. This zone is interpreted to incorporate the total, recently known range of *Berriasella (Malbosiceras) foraticostata* (Thieuloy). The range of this species, which undoubtedly has "Berriasian" affinities, apparently straddles the lower boundary of the *T. pertransiens* Subzone, for it commences below the massive entry of renownedly "Valanginian" forms amidst an association with only 'Berriasian' forms such as *B (B.)* aff. *callisto*, *T.* aff. *alpillensis*, *T.* cf. *donzei*, and *S. (S.) boissieri*; *B. (M.) foraticostata* disappears in the same bed as *S. (S.) boissieri*. Therefore the lower boundary of the *Th. (Th.) otopeta* Zone is probably, but only slightly, lower than the base of the original *T. pertransiens* Subzone.

Le Hégarat & Remane (1968) and Le Hégarat (1971) interpreted the latter as the lowest subzone of the *Th. (K.) roubaudianum* Zone as then conceived. The ammonite association that Le Hégarat (1971) gave confirms this. Unfortunately he did not give a faunistical characterization of the upper boundary of this subzone; in fact he characterized only its basal part (Le Hégarat, 1971, p. 287). It is therefore impossible to separate the lower part of the *T. pertransiens* Subzone as a distinct biostratigraphic unit, because this should always and inevitably be identical with the original *T. pertransiens* Subzone, which has priority over the *Th. (Th.) otopeta* zone. Thieuloy therefore perfected the ammonite association of the basal part of the *T. pertransiens* Subzone. In France the melange of Berriasian and Valanginian ammonite forms that allegedly would characterize the *Th. (Th.) otopeta* Zone seems to be restricted to the 2 m thick interval of overlap.

DATA FROM LOS MIRAVETES (SPAIN)

The succession of ammonite faunas in Los Miravetes is quite different from that of SE France and compels us to adopt a different interpretation of the boundary between the Berriasian and the Valanginian sensu stricto.

As in SE France, the base of the stratigraphic interval that can be correlated with the *B. (B.) callisto* Subzone is faunistically characterized by the end of the acmes of *Berriasella (Berriasella) picteti* (Jacob) and *B. (B.) jauberti* Maz., by the beginning of the acmes of *Tirnovella alpillensis* and *T. donzei*, and by the start of the range of *Lorenziella hungarica*. Like in SE France the "typically Berriasian" species *Subthurmannia (Subthurmannia) boissieri* (Pict.), *S. (S.) rarefurcata* (Pict.), *B. (B.) callisto* (d'Orb.), *T. alpillensis* (Maz.), *T. donzei* (Le Hég.), *Thurmanniceras (Erdenella) paquieri* (Sim.), and *Leptoceras studeri* (Oost.) were found throughout the stratigraphic interval correlated with this subzone. In addition several specimens of *Spiticeras (Spiticeras) tenuicostatum* Djan., *Sp. (Sp.)* n. sp. aff. *oppeli* (Uhl.), *Spiticeras (Kilianiceras) incertum* Djan., and the last representatives of *B. (B.) picteti* (Jacob), *B. (B.) jauberti* Maz., *Spiticeras (Groebericeras)* aff. *bifrons* (Leanza), and *Sp. (Sp.) multiforme* Djan. were collected from this interval.

In the beds directly above those in which the last representatives of *S. (S.) boissieri*, *S. (S.) rarefurcata*, *B. (B.) callisto*, *T. donzei*, and *Lp. studeri* were found (which in SE France marks the top of the *B.* [*B.*] *callisto* Subzone) appear like in SE France: *Tirnovella pertransiens* (Sayn) and its morphotype *valdrumensis* Sayn, *Thurmanniceras (Thurmanniceras) otopeta* Thieul., *Th. (Th.) allobrogicum* (Kil.), *Th. (Th.) salientinum* Sayn, *Thurmanniceras (Erdenella)* cf. *hystricoides* (Uhl.), and *Thurmanniceras (Kilianella) grossouvrei* Sayn. In addition appear Sayn's (1907) *Th. (K.) 'bochianensis'* var. comprimée (= *Th.* [*K.*] n. sp. aff. *bochianensis*), Mazenot's (1939) *'Th.* aff. *pertransiens'* (= *Tirnovella* n. sp. aff. *gueymardi*), and the form referred to by Arnaud et al. (1981) as *Tirnovella* aff. *alpillensis* (= *T.* aff. *alpillensis*).

The entry of this association clearly marks the base of the *T. pertransiens* Subzone. It should be mentioned that also the last representatives of typical *T. alpillensis* and the only representative of *Spiticeras (Spiticeras) correardi* (Kil.), were collected from these lower beds and that Wiedmann (in Allmann et al., 1975) reported the last *Spiticeras (Negreliceras)* cf. *negreli* (Math.) from the bed that produced the first *T. pertransiens*.

Higher in the *T. pertransiens* Subzone appear: *Thurmanniceras (Kilianella) ischnoterum* Sayn, *Th. (K.) roubaudianum* (d'Orb.), Sayn's (1907) variety of *Th. (K.) "bochianensis"* that he depicted on pl. 6, fig. 12 (= *Th.* [*K.*] aff. *bochianense*), *Thurmanniceras (Thurmanniceras) loryi* Sayn, *Tirnovella gueymardi gueymardi* (Sayn), and *Olcostephanus (Olcostephanus)* aff. *globulus* Spath. Also single specimens of: *Sarasinella varians* (Uhl.), *Sr. eucyrta* (Sayn), *Thurmanniceras (Thurmanniceras)* aff. *kingi* (Uhl.), *Parandiceras* cf. *theodori* (Uhl.) were found together with the last *Subthurmannia*, viz. *S. (S.) lissonoides* Spath.

The ammonite association that forms the faunal transition between the *T. pertransiens* association and the *Busnardoites campylotoxus* association is distinct enough to justify the introduction of a separate subzone. The "horizon à *Saynoceras hirsutum*" of Thieuloy (1973, 1977, 1979) falls within this subzone. As the ammonite fauna in this biostratigraphic unit at Los Miravetes is still too fragmentary to define a true Oppel-subzone in the proper way, this unit is provisionally kept in the state of assemblage-subzone and called the *Sarasinella trezanensis-Thurmanniceras (Kilianella) pexiptychum* Assemblage-subzone (Hoedemaeker, 1982).

In the lower part of this subzone appear: *T. gueymardi crassicostata* (Nikolov), *Sr. trezanensis* (Lory), *Sr. subquadrata* (Sayn), *N. subtenuis* Sayn, *Th. (K.) pexiptychum* (Uhl.) (typical form), cotype of *'Hoplites pexiptychum'* Uhlig, 1882 (= *Th.* [*K.*] n. sp. F), *Th. (K.)* cf. *bochianense* Sayn, *Olcostephanus (Rogersites) ambikyi* Besairie, *O. (R.)* aff. *schenki* (Op.) in Spath, 1939, and *Chamalocia aenigmatica* (Sayn). Worth mentioning is the fact that the last reputedly "Berriasian" *Th. (E.) paquieri* was found in this subzone as well as the last *Th. (Th.) otopeta* and *Spiticeras*.

The reason why the ammonite succession from Los Miravetes is of particular importance is the fact that in the stratigraphic interval that can be correlated with the *B. (B.) callisto* Subzone reputedly "Valanginian" ammonite forms appear in rather great diversity.

In the five basal metres of this interval (there is no sign of a hiatus) were collected the first *Tirnovella gratianopolitensis* (Sayn), *Thurmanniceras (Kilianella) retrocostatum* Sayn, *Th. (K.)* cf. *lucense* Sayn (only small fragments, which could not be identified with certainty), *Sarasinella longi* (Sayn), *Neocomites premolicus* Sayn, several other forms of *Neocomites*, Sayn's (1907) *Th. thurmanni*, échantillon presque typique (= *Th.* [*Th.*] aff. *thurmanni*), Sayn's (1907) variety of *"Th. Thurmanni"* that he depicted on pl. 5, fig. 1 (= *Tirnovella* n. sp. aff. *gratianopolitensis*), Sayn's (1907) *"Th. Thurmanni"*, variété à large ombilic (= *Tirnovella alpillensis*), Sayn's (1907) *Neocomites trezanensis"*, variété à tours étroits (= *Sarasinella* n. sp. aff. *trezanensis*), Sayn's (1907) *'Neocomites neocomiensis'*, variété plate à côtes fines et fasciculées (= *Pseudoneocomites* n. sp.) (*Pseudoneocomites* Hoedemaeker, 1982, type species *Hoplites Retowskyi* Sarasin & Schöndelmayer, 1901), Kilian's (1891) *"Hoplites Thurmanni"*, var. extrême à tubercules (= *Th.* [*Th.*] n. sp. B), and Memmi's (1965) *Kilianella* aff. *grossouvrei* (= *Th.* [*K.*] n. sp. aff. *grossouvrei*).

Higher in this interval appear: *Thurmanniceras (Kilianella)* aff. *lucense* Sayn (with fasciculated ribs in addition to those that are bordering the constrictions), Sayn's (1907) *Th. (K.) "Roubaudi"*, variété à tours plus embrassants (= *Th.* [*K.*] n. sp. G), and Pictet's (1867) *'Ammonites Astierianus'* from Berrias (pl. 18, figs. 3, 4) (= *Olcostephanus* [*Olcostephanus*]) cf. *sublaevis* Spath).

In the upper part of this interval appear: *Olcostephanus (Olcostephanus) sakalavensis* Besairie, and *Neocomites neocomiensis* (d'Orb.).

It should be noted that, with the exception of *Sarasinella longi*, Sayn's *'N. trezanensis'*, var. à tours étroits, Sayn's *Th. (K.) "Roubaudi"*, var. à tours embrassants, and *Th. (K.)* cf. *lucense*, all the above mentioned "Valanginian" forms were also found in the overlying *T. pertransiens* Subzone of Los Miravetes or even higher.

Also it should be mentioned that representatives of *Kilianella* already appear in the lower Berriasian and that at Los Miravetes their frequency in the upper Berriasian equals their frequency in the lower Valanginian sensu stricto. Therefore this subgenus could no longer be considered characteristic for the Valanginian sensu stricto.

In our columns the base of the *T. alpillensis* Subzone was drawn at the local entry of *T. gratianopolitensis* and the base of the *T. pertransiens* Subzone at the local appearance of its index species.

DISCUSSION

The faunal succession encountered at Los Miravetes has important consequences as to the stratigraphic position of the boundary between the Berriasian and the Valanginian sensu stricto.

The impoverished association of merely "Berriasian" ammonites that hitherto characterized the *B. (B.) callisto* Subzone in SE France, could not be found in the Miravetes section. Instead the stratigraphic interval that can be correlated with the *B. (B.) callisto* Subzone contains an ammonite association that is the summation of the ,,typical *callisto* association" and a substantial association of renownedly "Valanginian" ammonites that would hitherto have indicated the *T. pertransiens* Subzone. It is in this stratigraphic interval that the melange of Berriasian and Valanginian ammonite forms occurs. Because of the fundamental difference between the ammonite association collected from this stratigraphic interval at Los Miravetes and the association that hitherto defined the concept of the *B. (B.) callisto* Subzone, the latter name does not satisfy anymore. Nevertheless this association, which is composed of a fifty-fifty mixture of "Berriasian" and "Valanginian" ammonites, clearly represents a distinct, well-delimitable and well-recognizable biostratigraphic unit between the *B. (B.) picteti* Subzone and the *T. pertransiens* Subzone. *Tirnovella alpillensis* was chosen as the new index for this biostratigraphic unit; it is the most frequent ammonite in this unit in SE France as well as in SE Spain.

It is yet unexplicable why no 'Valanginian' ammonite forms have been recorded from the *B. (B.) callisto* Subzone in SE France. For several French sections, for instance the Berrias section, the existence of a hiatus, along which the main part of the *B. (B.) callisto* Subzone and the basal part of the *T. pertransiens* Subzone are missing, may be the explanation (Donze & Le Hégarat, 1965; Le Hégarat & Remane, 1968; Le Hégarat, 1971). This explanation, however, will no longer serve for other sections in SE France, for instance the La Faurie-Pusteau section, in which no trace of a hiatus has hitherto been detected. For these sections we must think of collection failure or of facial and ecological factors to account for the absence of "Valanginian" ammonites.

Wiedmann (in Allemann et al., 1975) already reported a similar mixture of 'Berriasian' and 'Valanginian' ammonites from SE Spain. Unfortunately the ammonite association he described from his *"B. (B.) callisto* Zone" of Los Miravetes cannot be relied on, because, due to a serious correlation error in the amount of overlap assumed for the different parts of the Miravtes section, he equated the stratigraphic interval occupied by the *T. alpillensis* Subzone with the interval occupied by the *T. pertransiens* Subzone. Due to this error *T. pertran-*

siens seems to be most abundantly present in his "*B. (B.) callisto* Zone", which motivated him to drop this species as index for the basal biostratigraphic unit of the Valanginian. Also *Th. (K.) lucense* was rejected as index, because it appears low in the "*B. (B.) callisto* Zone". Therefore he introduced his *Th. (Th.) thurmanni* Zone for the same biostratigraphic interval as defined for his former *Th. (K.) lucense* Zone, i. e. between the last *B. (B.) callisto* and the first *Th. (K.) roubaudianum.*

After correction of this correlation error, our investigation revealed that WIEDMANN's findings may be true for *Th. (K.) lucense,* but definitely not for *T. pertransiens,* which at Los Miravetes appears directly above the last *B. (B.) callisto.* Moreover also SAYN's *Th. Thurmanni,* échantillon presque typique (this juvenile specimen is generally interpreted as a true *thurmanni,* but I provisionally referred to it as aff. *thurmanni* because of the uncertain interpretation of the lectotype of *thurmanni* in PICTET & CAMPICHE, 1860, pl. 34, fig. 1, which is only an adult living chamber fragment) appears at the base of the interval that can be correlated with the *B. (B.) callisto* Subzone. As the motives for the introduction of the *Th. (Th.) thurmanni* Zone are without foundation, the concept of this zone should be abandoned.

The faunal successions reported by WIEDMANN (in ALLEMANN et al., 1975) from the Cañada Lengua sections (S of Caravaca), which are not disturbed by correlation errors, but which are very incomplete due to lacunas, show however that not only the ends of the ranges of *Pomeliceras nieri, S. (S.)*

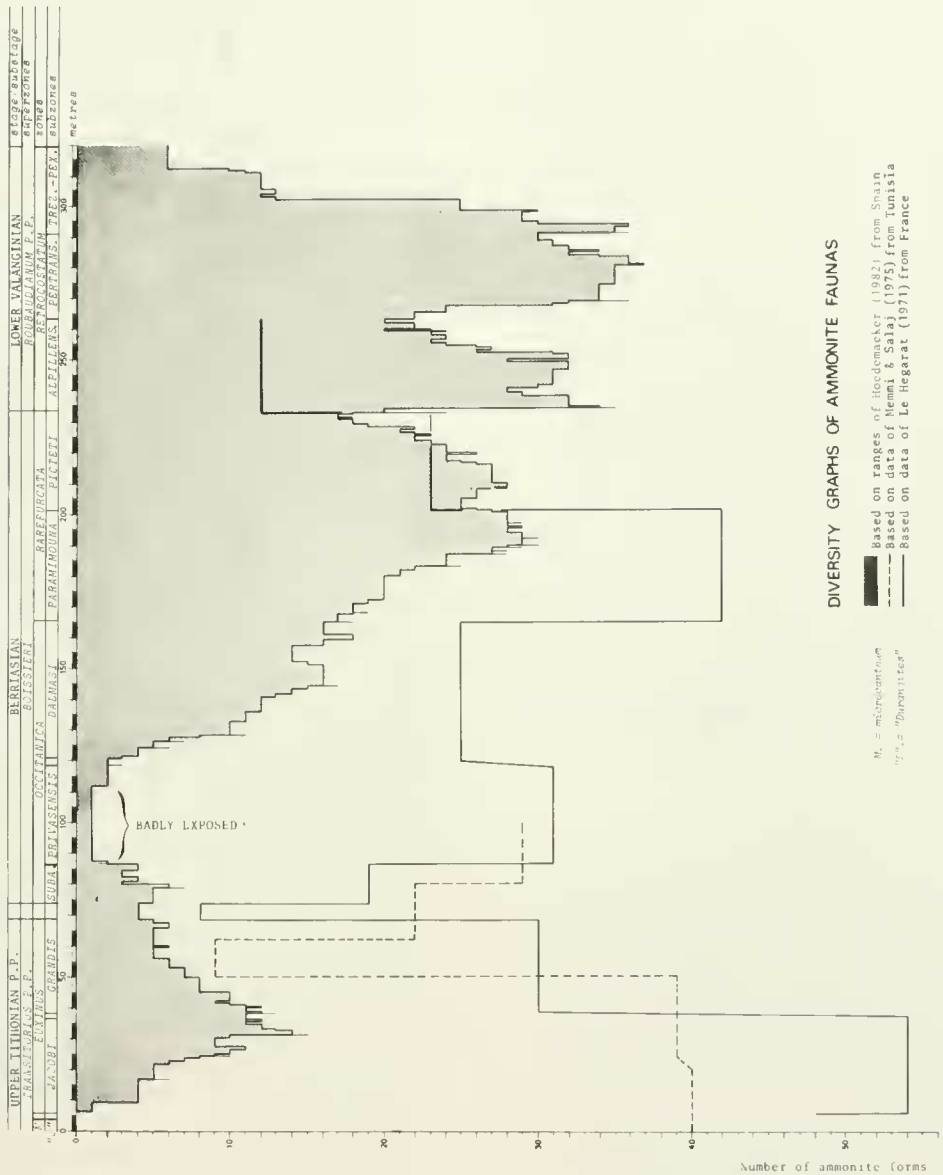


Figure 2. The number of ammonite forms at each level of the Los Miravetes section (Spain) is compared with the number of ammonite forms reported from each subzone in France by LE HÉGARAT (1971) and with the number of forms reported from the ammonite assemblages distinguished by MEMMI & SALAJ (1975) in Tunisia. The correlation of these assemblages with LE HÉGARAT's zonation was slightly modified. Haploceratids, lytoceratids, and phylloceratids are excluded from this comparison. The Miravetes diversity graph shows the deep low that separates the diversity highs of the *transitorius* and *boissieri* superzones, the low subsidary high of the *subalpina* Subzone, and the conspicuous subsidary high of the *alpillensis* Subzone between the diversity highs of the *boissieri* and *roubaudianum* superzones.

boissieri, and *Sp. (Ng.) negreli,* but also those of *B. (B.) callisto, Sp. (Ng.)* cf. *paranegreli,* and *Lp. studeri* are overlapping a few metres the beginning of the range of *T. pertransiens.*

When the diversity (= number of species) of the perisphinctacean ammonites of Los Miravetes was plotted bed by bed for the uppermost Tithonian, Berriasian, and lower Valanginian sensu stricto, a succession of pronounced diversity highs and lows became apparent (Fig. 2). At first I interpreted them as local diversity fluctuations. Changes in facies could not be held responsible for these highs and lows, because the facies remains unchanged at nauseam throughout the entire Miravetes sequence. However, several of these highs and lows turned out to be of supraregional extent, for it was possible to reconstruct similar diversity curves (Figs. 2, 3) with equally pronounced highs and lows at the same stratigraphic positions when we include in them all those Mediterranean ammonite forms whose ranges are known correct to a subzone, in particular those of Le Hégarat (1971) and Thieuloy (1977a, 1979) for SE France and of Memmi & Salaj (1975) for Tunisia. This justifies the conclusion that these highs and lows are not merely local aberrations, but are of important time-stratigraphic significance, the more so as it turned out that the diversity minima correspond with the terminations of known regressive periods in the Mediterranean realm.

Each diversity minimum is preceeded by a stratigraphic interval in which disappearances of faunal elements highly predominate over appearances of new elements and is followed by an interval in which new appearances predominate over disappearances. Consequently each diversity high has its very own diagnostic fauna of perisphinctacean species and (sub)genera, which is quite different from the fauna of the adjacent diversity highs. Across a diversity minimum the transformation of the fauna appears to be rapid and profound, whereas in between the minima the successive ammonite faunas imperceptibly shade off into one another. The broad highs, therefore, represent successive natural ammonite assemblages, which form the raw material for the distinction of major biostratigraphic units, superzones, in the Mediterranean province, whereas the deep minima delimit distinct steps in the development of the ammonite faunas. Similar steps can be demonstrated for the faunal successions reported from Bulgaria, The Crimea, and Roumania.

So it turns out that the "episodic faunal revolutions", as Wiedmann (1973) called the rapid faunal turnovers used to determine the lower boundaries of the Triassic and Jurassic systems, are much more frequent than hitherto assumed. Many of these turnovers, however, come about mainly at the genus/species level and are therefore less manifest, although the slaughter among the ammonites is often of the same order. Even the five phases recognized by Wiedmann (1973) in the development of the ammonite faunas can, with a slight modification, be distinguished within the diversity highs of Los Miravetes and form the basis for the recognition of subzones (Fig. 3). The shape of the diversity graph is comparable to the one predicted by Carr & Kitchell (1980).

I am convinced that the recognition and determination of the presumably large number of such rapid faunal turnovers attended by conspicuous diversity lows provides a valuable means to give the delimitation of many biochronological units the objective basis that stratigraphers are so eager to obtain.

The superzones thus delimited in Los Miravetes have been given biostratigraphic names. The ammonite associations within the broad highs practically correspond to the original faunistical concepts of the *Paraulacosphinctes transitorius* Zone sensu Neumayr (1871) and Sapunov (1977), the *Subthurmannia (Subthurmannia) boissieri* Zone sensu Kilian (1888) and the "Colloque sur le Crétacé inférieur" (1965), and the *Thurmanniceras (Kilianella) roubaudianum* Zone sensu Kilian (1888, 1896). These turn out to be real, practical, and well-delimitable biostratigraphic units and were therefore restored in their original sense, but their concepts were of course corrected and adapted a little in accordance with the greater knowledge we have now of the distribution of ammonites. This means, however, that *S. (S.) boissieri* and *Th. (K.) roubaudianum* are not available anymore as index species for the upper Berriasian and the lower Valanginian sensu stricto. The index fossils of these zones are therefore replaced by *S. (S.) rarefurcata* and *Th. (K.) retrocostatum* respectively (Hoedemaeker, 1982) (Fig. 3).

The superzones are separated from each other by faunal transitions in which the faunal elements of the foregoing superzone rapidly disappear to make room for the new faunal elements of the next superzone, which gradually, though rapidly and simultaneously with this disappearance, increase in number and diversity to reach their maximum in the upper part of that superzone. These faunal transitions give rise to narrow subsidary diversity highs, because the diversity of such transitional association is the summation of the old and the new faunal elements. These small diversity highs are situated within the deep lows. The transitional faunas should be incorporated in the superzone that immediately follows them, because the entry and the rapid increase in number and diversity of the faunal elements that characterize the following superzone is biostratigraphically more important than the retarded presence of some faunal elements of the foregoing superzone. Besides the deepest parts of the diversity lows form the lower limits of these subsidary highs. These transitional faunal associations therefore should constitute the basal subzones of the superzones.

For the *S. (S.) boissieri* Superzone this is apparently the *Subthurmannia (Strambergella) subalpina* Subzone, which builds only a low subsidary high. For the *Th. (K.) roubaudianum* Superzone this is apparently the *T. alpillensis* Subzone, which builds a narrow, but conspicuous subsidary high. The next superzone undoubtedly begins with the *Himantoceras trinodosum* Subzone, which also builds a low subsidary high within a deep diversity low, which is attended by a rapid and nearly complete renewal of the ammonite fauna.

So the faunal coupures at the base of the *S. (St.) subalpina* Subzone and the *H. trinodosum* Subzone are more important than the one at the base of the *T. alpillensis* Subzone. Nevertheless the faunal turnover in the latter subzone, brought about by the rapid incoming of new faunal elements and their progressive increase at the expense of the old ones, is profound and rapid enough to warrant the delimitation of superzones. Therefore it becomes obvious that the *Th. (K.) roubaudianum* Superzone and consequently also the Valanginian sensu stricto should begin at the diversity minimum at the base of the *T. alpillensis* Subzone. This level practically coin-

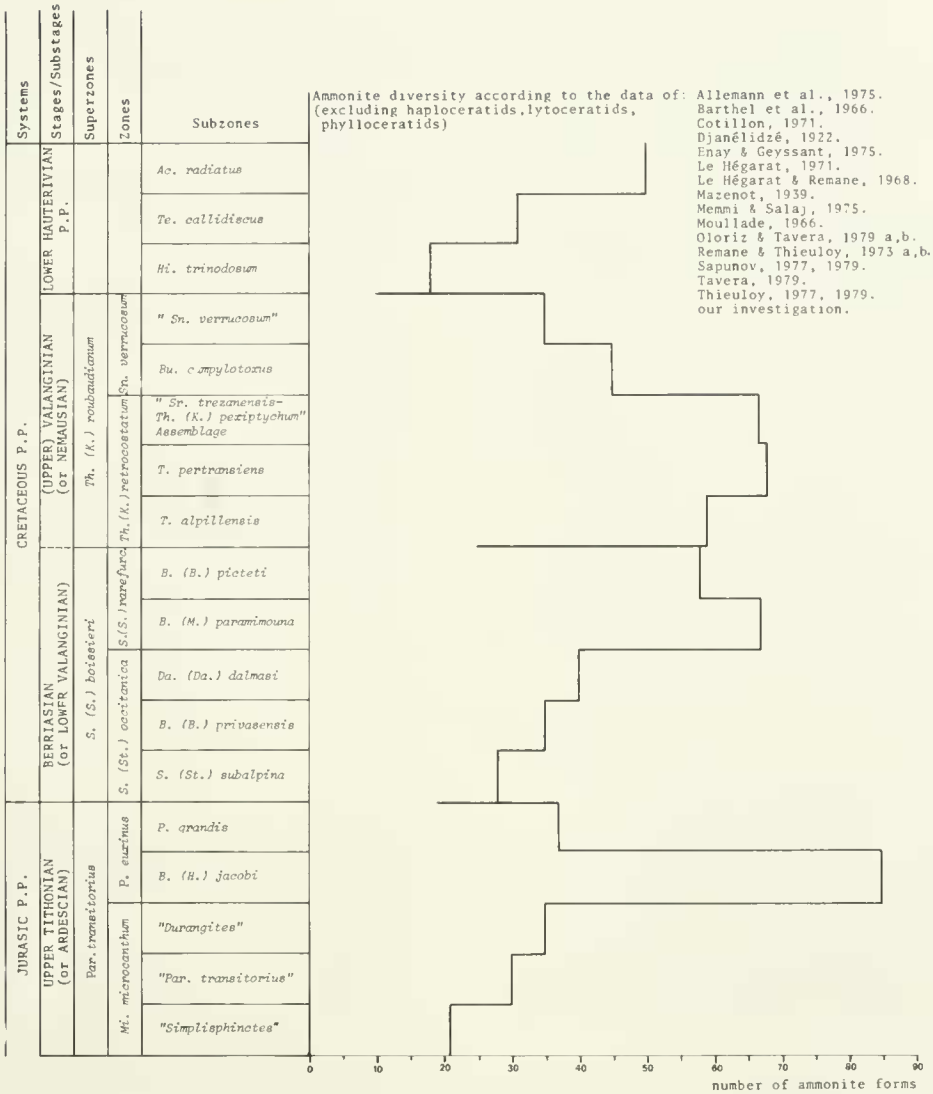


Figure 3. Stratigraphical subdivision adopted in this paper. For each subzone the total number of those Mediterranean ammonite forms (excluding haploceratids, lytoceratids, and phylloceratids) whose ranges are at present known correct to a subzone is given to show the pronounced diversity highs and lows of supraregional extent that had best be used to delimit the stages. BAUMBERGER (1903–1910) should be added as one of the source references.

cides with the base of the calpionellid subzone D3 (= the entry of *Lorenziella hungarica)* and can be correlated with the base of the French *B. (B.) callisto* Subzone.

The faunal caesura that separates the *Pseudosubplanites grandis* Subzone from the *S. (St.) subalpina* Subzone was proposed to mark the Tithonian-Berriasian boundary (HOEDEMAEKER, 1981, 1982). The deep faunal coupure that separates the "*Saynoceras verrucosum*" Subzone (in the restricted sense as used by MOULLADE, 1966, MOULLADE & THIEULOY, 1967, THIEULOY, 1971, 1973, 1977b, 1979) and the *Himantoceras trinodosum* Subzone clearly separates a Valanginian from a Hauterivian ammonite assemblage. As the latter break is accidentally, but fortunately closest to (if not coinciding with) the lower boundary of the Hauterivian stratotype (cf. DONZE & THIEULOY, 1975) as it was originally indicated by RENEVIER (1873), i. e. at the base of the 'marnes á Astieria', there is no impediment to choose it as the Valanginian-Hauterivian boundary (HOEDEMAEKER, 1982).

As the stratigraphic scope of the Berriasian and the Valanginian sensu stricto are herewith reduced to only one superzone (= 5 subzones) each, the stage appreciation that the Berriasian has gradually acquired (MAZENOT, 1939; Colloque sur le Crétacé inférieur, 1965) should be seriously questioned. It is proposed here to return to the old concept and to subdivide the original scope of the Valanginian Stage (excluding the so-called "Terrain Dubisien") into a lower substage, the Berriasian, and an upper substage, for which the name Nemausian (SARRAN D'ALLARD, 1875, 1881) is available. The Nemausian (from Nemausus = Latin for Nîmes) has explicitly been introduced as the stage between the Berriasian and the Hauterivian and it would constitute together with the Berriasian the two divisions that compose the "Terrain Valanginien".

CONCLUSIONS

It is shown that in the sequence of Los Miravetes (west of Caravaca, SE Spain) the faunal turnover at the boundary between the Berriasian and the Nemausian (= Valanginian sensu stricto) is definitely not as abrupt as has generally been assumed. The faunal transformation, though important because it involves the nearly complete renewal of the ammonite fauna in a relatively short lapse of time, is much slower than previously thought and comes about in the course of the entire *T. alpillensis* Subchron, which corresponds with Le Hégarat's *B. (B.) callisto* Subchron.

It is shown that in this subchron the successive extinctions of "typically Berriasian" taxa were at the same time compensated by the successive appearances of new "Valanginian" taxa. The faunal turnover has definitely not the abruptness that invited so many stratigraphers to choose this boundary as the limit between the Jurassic and Cretaceous systems.

On account of the entry and the rapid increase in number and diversity of ammonites that characterize the *Th. (K.) roubaudianum* Superzone, the boundary between the Berriasian and the Nemausian (or Valanginian sensu stricto) should be drawn at the base of the *T. alpillensis* Subzone, which virtually coincides with the base of calpionellid subzone D3.

The concept of the *B. (B.) callisto* Subzone should be abandoned, because its faunal concept is very inadequate, but also those of the *Th. (K.) lucense, Th. (Th.) thurmanni,* and *Th. (Th.) otopeta* "zones" should be abandoned, because they do not differ essentially from the concept of the *T. pertransiens* Subzone, which has priority.

The breaks in the faunal succession of the Mediterranean perisphinctacean ammonites between the *P. grandis* and *S. (St.) subalpina* subzones, where the boundary between the Tithonian and the Valanginian stages had best be drawn, and between the "*Sn. verrucosum*" Subzone (in the restricted sense used by Moullade and Thieuloy) and the *Hi. trinodosum* Subzone, where the boundary between the Valanginian and the Hauterivian stages had best be drawn, are more important and the faunal transformations at these levels more radical than between the *B. (B.) picteti* and *T. alpillensis* subzones, where the boundary between the Berriasian and Nemausian substages had best be drawn.

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